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DDT PERSISTENCE IN WILD HARES AND MINK

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Abstract: Residue data in wild hares (*Lepus americanus*) and mink (*Mustella vison*) following light applications of DDT to the forest are presented. Residues of from 0.5 to 2.0 ppm DDT and its metabolites are shown to persist in mink up to 9 years after a single application of 1 lb/acre. Results of analyses of adult hares and hare fetuses show low residue levels throughout 10 years following spraying that are not significantly different ($P < 0.05$) from levels found in hares from untreated forests. Patterns of DDT residue levels and persistence shown for these species are compared with similar patterns shown for other mammalian herbivores and predators.

The contamination of a resident fauna from prolonged DDT persistence in soil has been documented (Dimond et al. 1968*a*, 1968*b*; Dimond and Sherburne 1969). DDT in the environment is reflected in varying patterns of persistence in animals occupying different trophic levels (Meeks 1968, Woodwell et al. 1967). It has been demonstrated that DDT and other slowly degrading materials are systematically concentrated in the upper layers of trophic pyramids (Walker et al. 1967). We present residue data from wild populations of two species of mammals illustrating the above points. Our study involves data from forests that received single, 1 lb per acre applications of DDT within the past 10 years.

These investigations have been made in areas sprayed for control of the spruce budworm (*Choristoneura fumiferana*) in northern Maine. Aerial applications were carried out by the State of Maine Forest Service in 1958, 1960, 1961, 1963, 1964, and 1967, covering 55,000–475,000 acres. There was considerable overlapping of treatments from year to year, but sizable areas were treated only once, from 1–10 years in the past. Additional areas were treated two or three times. Samples from surrounding forests of similar type and with no history of treatment were used as controls. Fig. 1 illustrates the mosaic of treatment plots comprising the study area.

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MATERIALS AND METHODS

Mink were collected in northern Maine during November, 1967, by several trappers. The skinned carcasses were held in plastic bags in freezer storage at -21 C until preparation for analysis for DDT residues. At that time, the digestive tracts were removed and saved for analysis of stomach contents. The latter will be the subject of a separate report. The remaining viscera were left in the carcass. Each specimen was ground in a food mill, mixed, and divided into 25 g subsamples, one or more of which were analyzed for DDT content. Extraction procedures, gas chromatographic analysis, con-

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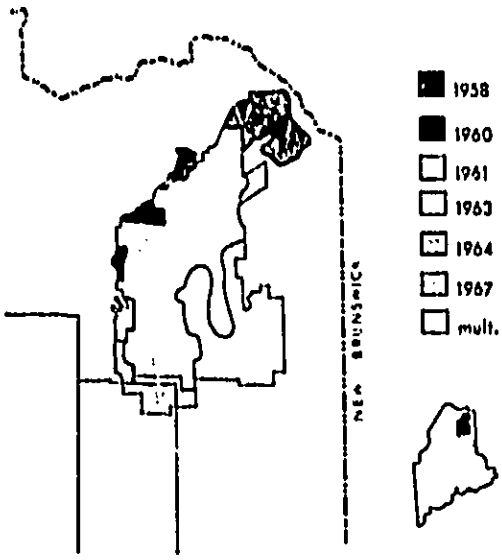

Fig. 1. Map of study area in northeastern Maine illustrating years of DDT application. Smaller insert map illustrates location of study area within the state.

Table 1. Total residues of DDT and metabolites in hares collected from areas with variable treatment history, presenting mean, range, and sample size.

YEARS SINCE TREATMENT WITH 1 LB/ACRE	TOTAL RESIDUES (ppm)	
0–1	0.08 (0–0.16)	(4)
5	0.04 (0–0.11)	(6)
10	0.02 (0–0.10)	(12)
Untreated	0.01 (0–0.08)	(13)
Treated 2 and 3 times	0.03 (0–0.17)	(28)

firmation of residue identities, and laboratory controls were as reported by Dimond et al. 1968*a*. Recovery of DDT and its metabolites averaged 85 percent. The residues were expressed as wet weight concentrations in whole animals minus the digestive tracts.

Because specimens obtained from trappers had been skinned, it was necessary to correct the data for amounts of DDT present in the hide. A correction factor was calculated based upon the analysis and comparison of residues in several carcasses and skins of wild weasels (*M. erminea*) and ranch mink.

Varying hares were shot during June and July of 1967 and 1968, along logging and secondary roads remote from agricultural lands or human habitation. From 4 to 12 hares were collected from plots treated once, 28 were shot within areas treated two and three times, and 13 were taken from untreated sites surrounding the sprayed areas.

The specimens were treated similarly to the mink prior to extraction, and the same method of subsampling was followed. Feet and digestive tracts were removed before grinding, but skins were included in the samples. Six of the females were pregnant, and the fetuses were separately analyzed as whole specimens for DDT residues.

RESULTS

Residues in hares tended to be very low (Table 1). Analysis of variance of residues in animals from treated and untreated plots showed insignificant differences ($P > 0.05$). DDE and DDD comprised 13–21 percent and 0–12 percent, respectively, of total DDT residues in adult hares, excepting those from year of spray, where DDE comprised only 3 percent of the total.

Fetuses that were analyzed for DDT residues and compared with values for their mothers varied greatly (Table 2). Again, the levels were generally very low ranging from < 0.005 to 0.169 ppm. The sample numbers were too small to assess the degree of passage of DDT across the placental barrier. In all fetuses analyzed, the percentage of DDD was greater than DDE, comprising 36 and 14 percent, respectively, of the total DDT residue.

As stated before, a conversion factor was necessary to adjust the residue data for

Table 2. Comparison of total residues of DDT and metabolites in pregnant hares and their fetuses.

Specimen No.	Total Residue of Female Hare (ppm)	Total Residue of Fetuses (ppm)
125-68	0.09	<0.005
		<0.005
		<0.005
2-68	0.03	0.02
	0.08	0.02
		0.02
		0.02
102-68	<0.005	0.02
		0.01
		0.01
		0.01
115-68	0.08	0.17
		0.02
		0.02
		0.01
111-68	0.06	<0.005
		0.08
		0.03
113-68	<0.005	0.01
		0.07
		0.07

mink. Table 3 presents residue data in skins and carcasses of weasels and ranch mink used to convert data from wild mink that were skinned. The skin comprises 17 percent of the total body weight but contains a higher concentration of residue, probably in subcutaneous fat. Carcass residues in mink were multiplied by 1.3 to compensate for the loss of the skins.

Residues of DDT in mink were considerably higher than in hares, and there was

Table 3. Converted total body residues of DDT and metabolites from residues in carcasses and skins of weasels and ranch mink, based upon skin comprising 17 percent of total body weight.

Animal	Residue in Body (ppm)	Residue in Skin (ppm)	Conversion Factor	Converted Total Body Residue (ppm)
Weasel	0.52	1.00	1.2	0.02
Weasel	0.13	0.40	1.3	0.18
Mink	0.16	0.56	1.5	0.22
Mink	0.05	0.13	1.2	0.07
Mink	0.85	1.47	1.1	0.96

Table 4. Corrected total residues of DDT and metabolites in mink collected from areas with variable treatment history, presenting mean, range, and sample size.

Years Since Treatment with 1 lb per Acre:	Total Residues (ppm)	
0	8.5 (4.4-12.3)	(2)
7	1.3 (0.4-3.0)	(4)
9	1.0 (0.5-2.0)	(13)
Untreated	0.2 (0.04-0.5)	(14)

evidence of prolonged persistence, with residues at 7 and 9 years after application well above levels in animals from unsprayed areas (Table 4). Coefficients of variation for animals from the three different treatment plots and the controls ranged from 55.7 to 77.6 percent and averaged 66.1 percent. A Duncan's test showed significant differences ($P < 0.05$) between the means of the residue levels of the controls and of all treatments combined. Within treatments, significant differences ($P < 0.05$) occurred between the 1967 spray area (0 years since spray) and other treatments; however, no significant differences ($P > 0.05$) were found between the residue levels for 7 and 9 years after spray.

DISCUSSION

Dimond and Sherburne (1969) have discussed *residue persistence in small mammals*. Those data can be compared with the results described in the present study with regard to trophic level of the various species. The above authors found that mice (*Peromyscus* sp.) and voles (*Clethrionomys gapperi*) accumulated their highest levels of DDT, about 1.0 ppm, during the year of spray. These values subsequently declined and residue levels approached pretreatment levels after 6–7 years.

Shrews (*Blarina brevicauda, Microsorex hoyi*) on the other hand, were found to contain from 10–40 times the total residue car-

ried by mice and voles in all treatment areas. Residues remained significantly above pretreatment levels through 9 years following a single application. High mean residues of 15.0 ppm in the year of treatment, declined to 2.5 ppm by 3 years after application, but remained at about this level with little apparent decline thereafter.

The hares examined in the present study showed a residue persistence pattern similar to that in mice and voles but at a lower level and with less evidence of contamination in the years following treatment. This no doubt reflects the different feeding habits of the small mammals and hares, as mice and voles take some invertebrate animals in the diet while hares are exclusively herbivorous.

Mink, on the other hand, demonstrated the considerably higher and more persistent residue accumulations that we would expect in a carnivore. Residue levels in mink were from 10 to 90 times the total residues in hares. Residue levels after 7 and 9 years were still significantly above pretreatment levels. In these respects, mink appear to show residue levels and persistence patterns very similar to those found in shrews (Dimond and Sherburne 1969).

The protracted persistence of DDT in forest soils has been well-documented (Woodwell and Martin 1964), but there is little evidence of persistence in living plant material. Residue levels in mammals in the years following application reflect these different levels of DDT retention dependent upon their trophic position. The low levels and lack of persistence noted in hares is in agreement with DDT levels found in herbivores in other studies following application of DDT to the forest (Pillmore and Finley 1963, Walker et al. 1965). Deciduous and herbaceous foliage apparently contains little or no DDT 1 year following application; this results in slight contamination in animals feeding on this material.

The higher levels and prolonged contamination in carnivores must be derived ultimately from the persistent soil residues. Mink are at the peak of a pyramidal food web and prey heavily on crayfish, fish, small mammals, and birds (Grinnell et al. 1937). Persistent DDT residues have been demonstrated to occur in certain species in all of these groups (Dimond et al. 1968*b*, Dimond and Sherburne 1969, Cottam 1965, DeWitt et al. 1963, Rudd 1964). Shrews feed heavily on earthworms, slugs, and ground beetles (Hamilton 1930, Rudge 1968). These dietary items are closely associated with soils and are animals that can concentrate DDT from soil residues (Davis 1968).

Food chain magnification of DDT is indicated by the higher residue levels in mink and shrews compared to hares, mice, and voles. It is surprising, however, that residue levels in mink were somewhat lower than those in shrews since the former appear to occupy a higher trophic position. The very high metabolic rate of shrews may account in part for this difference. Without detailed quantitative information on the exact diet and DDT content of each item for the two types of animals, this discrepancy cannot be explained.

Levels of DDT in herbivores, following DDT application to the forest, appear very low and may be of questionable significance to the animals themselves. With little persistence, there is little danger of cumulative buildup with repeated treatments. This was illustrated for the hares from areas treated two or three times (Table 1). Animals in these niches can perhaps tolerate DDT application at quantities and frequencies normally used in forest insect control.

The outlook is not as clear for the car-

nivores. In addition to accumulating greater quantities of DDT initially, the persistence of these residues leads to cumulative effects if there are subsequent DDT treatments. This could not be demonstrated with mink because of the absence of samples from plots treated two or three times. Such cumulative levels were noted in shrews (Dimond and Sherburne 1969), however, and are assumed to occur in mink.

The highest level of DDT in mink was in the year of treatment (Table 4) and was well below lethal levels suggested for ranch mink by Aulerich et al. (1968). Gilbert (1969), however, showed that total blood counts decreased and embryonic loss increased in ranch mink fed very low quantities of DDT and its metabolites over several months. Residue analyses of these animals showed levels which appear comparable to those we report in wild mink 7 and 9 years after a single DDT application to the forest. Direct comparison of the two studies is difficult since Gilbert analyzed selected organs of mink rather than whole bodies. This evidence does suggest, however, that the DDT residue levels we find persisting in mink and several other predators for long periods following a single insect control program can produce physiological changes in mink under laboratory conditions. The significance of this in nature cannot presently be specified, but it invites study.

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